Claims

1. Bidirectional signal processing method for the robust parallel transmission of digital transmit data streams in regular and singular radio channels of a multiple input-multiple output radio transmission system (MIMO system) having n_T transmit antennas and n_R receive antennas with a rank-adaptive matching of the data transmission rate to the total currently available channel capacity while keeping constant the maximum transmit power P_{tot} as the sum of all subchannel powers P_i where $i = 1...\min(n_T, n_R)$, with the rank-adaptive matching of the data transmission rate in respect of the channel matrix $\mathbf{H}$ to the currently available channel capacity being performed by means of a variation, continuously adjusted to the current channel behavior, of n_d currently used subchannels and the spectral efficiency K of the at least one selected coding and modulation method, comprising the following method steps which are to be cyclically repeated:

I) Determination of the channel matrix $\mathbf{H}$ on the transmit and the receive side of the MIMO system according to

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n} \qquad (1)$$

where $\mathbf{y}$ = receive vector

$\mathbf{x}$ = transmit vector

$\mathbf{n}$ = noise vector

II) Singular value decomposition $SVD(\mathbf{H}) = \mathbf{U}\mathbf{D}\mathbf{V}^H$ of the known channel matrix $\mathbf{H}$ with the maximum rank $(n_T \times n_R)$ on the transmit side and the receive side of the MIMO system for determining the unitary transformation matrices $\mathbf{U}$ and $\mathbf{V}$ as well as the diagonal

matrix **D** containing the ordered singular values $\sqrt{\lambda_i}$ derived from the eigenvalues λ_i of the subchannels on the left main diagonal.

III) Modification of the transmit data vector **x** on the transmit side of the MIMO system by means of a linear matrix-vector multiplication according to

$$\mathbf{x} = \frac{1}{\gamma}\mathbf{V}\ \mathbf{Q}\ \mathbf{d} \qquad \textbf{(2)}$$

where $\gamma = \sqrt{\sum_{i=1}^{n_d} \frac{P_1}{P_{tot}}} =$ = amplification factor for limiting the total transmit power P_{tot},

where **V** = right unitary transformation matrix according to II)

where **Q** = diagonal transmit matrix containing the values $\sqrt{P_i}$ on the left main diagonal and

where **d** = current transmit data vector containing the variable length $n_d \leq \min(n_T, n_R)$ from the support of n_d subchannels for the parallel transmission of the transmit data streams

IV) Multiplication of the currently received transmit data vector **d'** on the receive side of the MIMO system where $\gamma\mathbf{U}^H$, from which through insertion according to I) and II) it follows

$$\mathbf{d^*} = \gamma\mathbf{U}^H\mathbf{y} = \mathbf{D}\cdot\mathbf{Q}\cdot\mathbf{d} + \gamma\mathbf{U}^H\mathbf{n} \qquad \textbf{(3)}$$

V) Determination of the n_d components d_k^* of the currently received, modified transmit data vector **d*** from IV) according to

$$d^*_k = \sqrt{\lambda_k \cdot P_k} \cdot d_k + \gamma \cdot \tilde{n}_k \qquad \textbf{(4)}$$

where $k = 1 \ldots n_d$

VI) Selection of the subchannel powers P_i according to

a) with an optimal rank-adaptive support for all subchannels $P_i > 0$ based on the water-filling principle WF according to

$$P_i = \left(\mu - \frac{\sigma_n^2}{\lambda_i}\right)^+ \qquad \textbf{(5)}$$

where $(a)^+ = 0$ for $a = 0$ and $(a)^+ = a$ for $a \neq 0$

where μ = fill factor which is chosen so that $\sum_{i=1}^{n_d} P_i = P_{tot} \Rightarrow \gamma = 1$

where σ_n^2 = noise power at the receiver (normalizable to 1)

which yields the number n_d of the currently usable subchannels for a modification of the current transmit data vector **d** according to

$$n_d = \left|\{i : P_i > o\}\right| \qquad \textbf{(6)}$$

and which yields a variable signal-to-noise ratio according to

$$SNR_k^{WF} = \frac{\lambda_i \cdot P_i}{\sigma_n^2} \tag{7}$$

or

b) with a suboptimal rank-adaptive support for all subchannels according to the adaptive channel inversion principle ACI where **DQ = I** where **I** = unity matrix for a complete interference cancellation according to

$$P_i = \frac{1}{\lambda_i}, \tag{8}$$

where the number n_d of the currently usable subchannels is selected for a modification of the current transmit data vector **d** such that the spectral efficiency K of the transmission is maximized and a constant signal-to-noise ratio is produced according to

$$SNR_k^{ACI} = \frac{P_{tot}}{\sigma^2 \sum_{i=1}^{n_d} \frac{1}{\lambda_1}} \tag{9}$$

VII) Selection of the optimal coding and modulation method based on the determined signal-to-noise ratio SNR_k^{WF} or SNR_k^{ACI} with specification of a bit error rate BER to be complied with, where

in case **a)** of the optimal rank-adaptive channel support, the optimal coding and modulation method is selected in each case for each of the n_d active subchannels or

in case **b)** of the suboptimal rank-adaptive channel support, a common coding and modulation method is selected for all n_d active subchannels.

2. The bidirectional signal processing method as claimed in claim 1, comprising a selection of the optimal coding and modulation method according to method step VII)a) by means of an individual numerical comparison of the determined values SNR_k^{WF} for the currently activated subchannels with the *SNR* values which are required for a specific coding and modulation method which enables the specified bit error rate BER to be complied with using the currently available subchannel powers P_i.

3. The bidirectional signal processing method as claimed in claim 1, comprising a selection of the optimal coding and modulation method according to method step VII)b) by means of an overall numerical comparison of the determined value SNR_k^{ACI} for all currently activated subchannels with an *SNR* value which is required for a specific coding and modulation method which enables the specified bit error rate BER to be complied with using the maximum transmit power P_{tot}, with a power increase being included through the support for the currently activated subchannels on the basis of the current, transmitter-side singular value decomposition.

4. The bidirectional signal processing method as claimed in one of the claims 1 to 3, comprising a transmission of the current number n_d of activated subchannels, as determined on the transmit side, to the receive side via a signaling channel.

5. The bidirectional signal processing method as claimed in one of the claims 1 to 4, comprising a front-end compensation on the transmit side of statistical fluctuations in the maximum transmit power of the MIMO system.

6. The bidirectional signal processing method as claimed in one of the claims 1 to 5, comprising a selection of the transmit covariance matrix $Q = D^{-1}$ for matching all currently active subchannels to an identical performance, with the factor γ

is yielded as :
$$\gamma = \sqrt{\sum_{i=1}^{n_d} \frac{1}{\lambda_1}}$$

7. The bidirectional signal processing method as claimed in one of the claims 1 to 6, comprising a M1MO system which operates according to the Time Division Duplex transmission method.

8. The bidirectional signal processing method as claimed in one of the claims 1 to 7, comprising a MIMO system in which the channel estimation in the uplink is reused for the signal processing in the downlink and vice versa.

9. The bidirectional signal processing method as claimed in one of the claims 1 to 8, comprising a source commonly coded and modulated on the transmitter side for all the data streams to be transmitted in parallel.

10. The bidirectional signal processing method as claimed in one of the claims 1 to 9, comprising a decomposition of the transmit and receive signal by means of the known OFDM method into a

plurality of subcarrier signals, with the bidirectional signal processing method being performed for each subcarrier signal.